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(54) HEATER JACKET FOR A FLUID LINE

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CPC ***F16L 53/008*** (2013.01); *Y10T 137/0318* (2015.04); *Y10T 137/6416* (2015.04)

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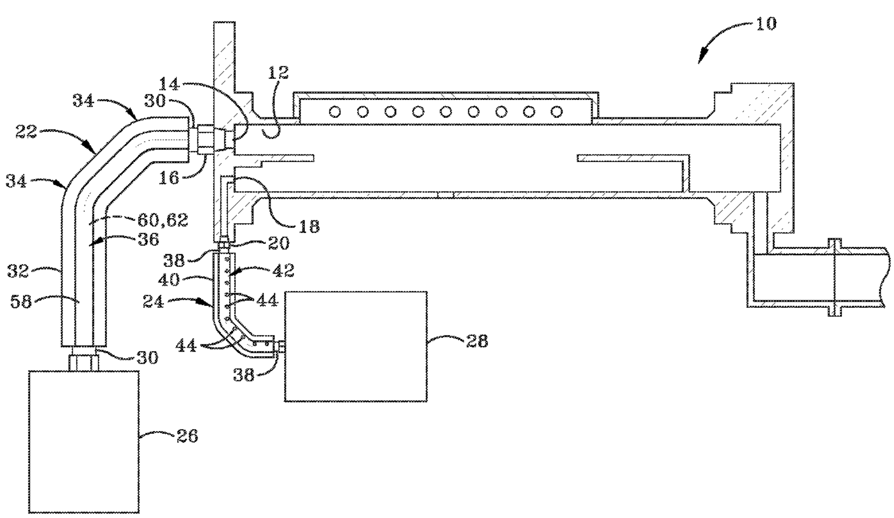
(57) ABSTRACT

A heater jacket for a fluid line including a tube having an inner surface and an outer surface; a spacer disposed within the tube between the inner surface and the fluid line; and wherein the spacer includes a hole for receiving the fluid line therein and spaces the fluid line from the tube inner surface.

24 Claims, 4 Drawing Sheets



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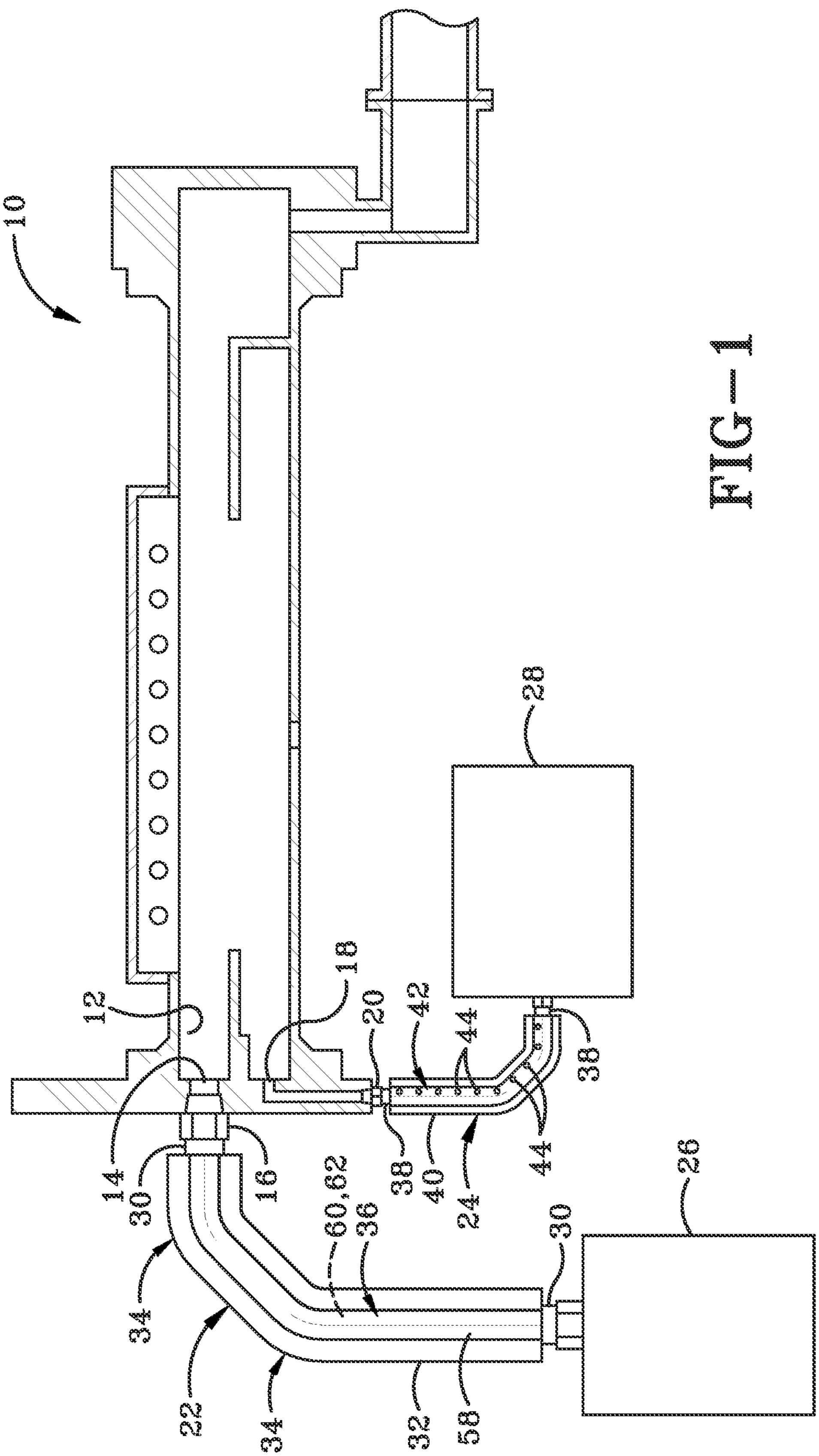
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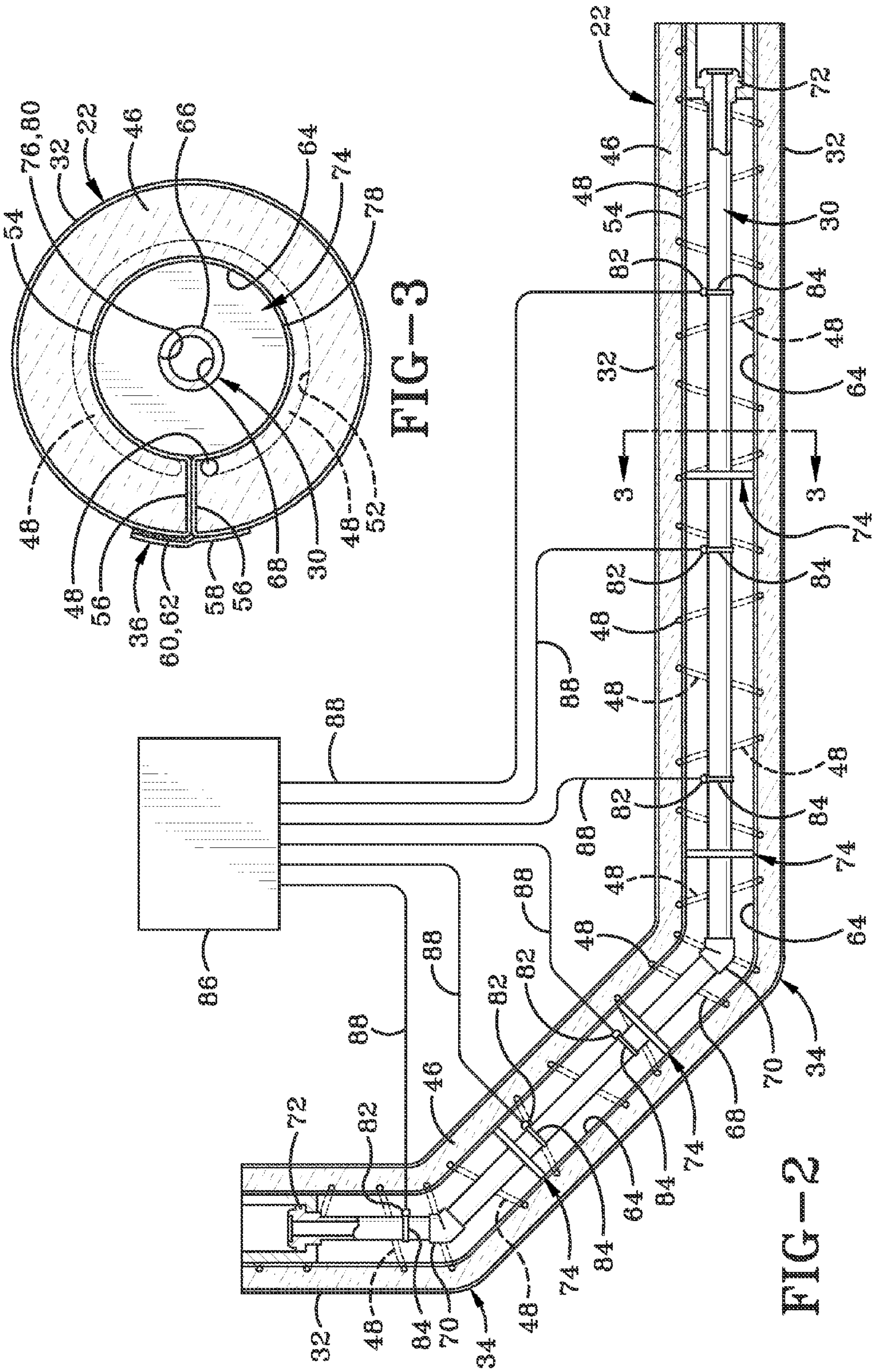
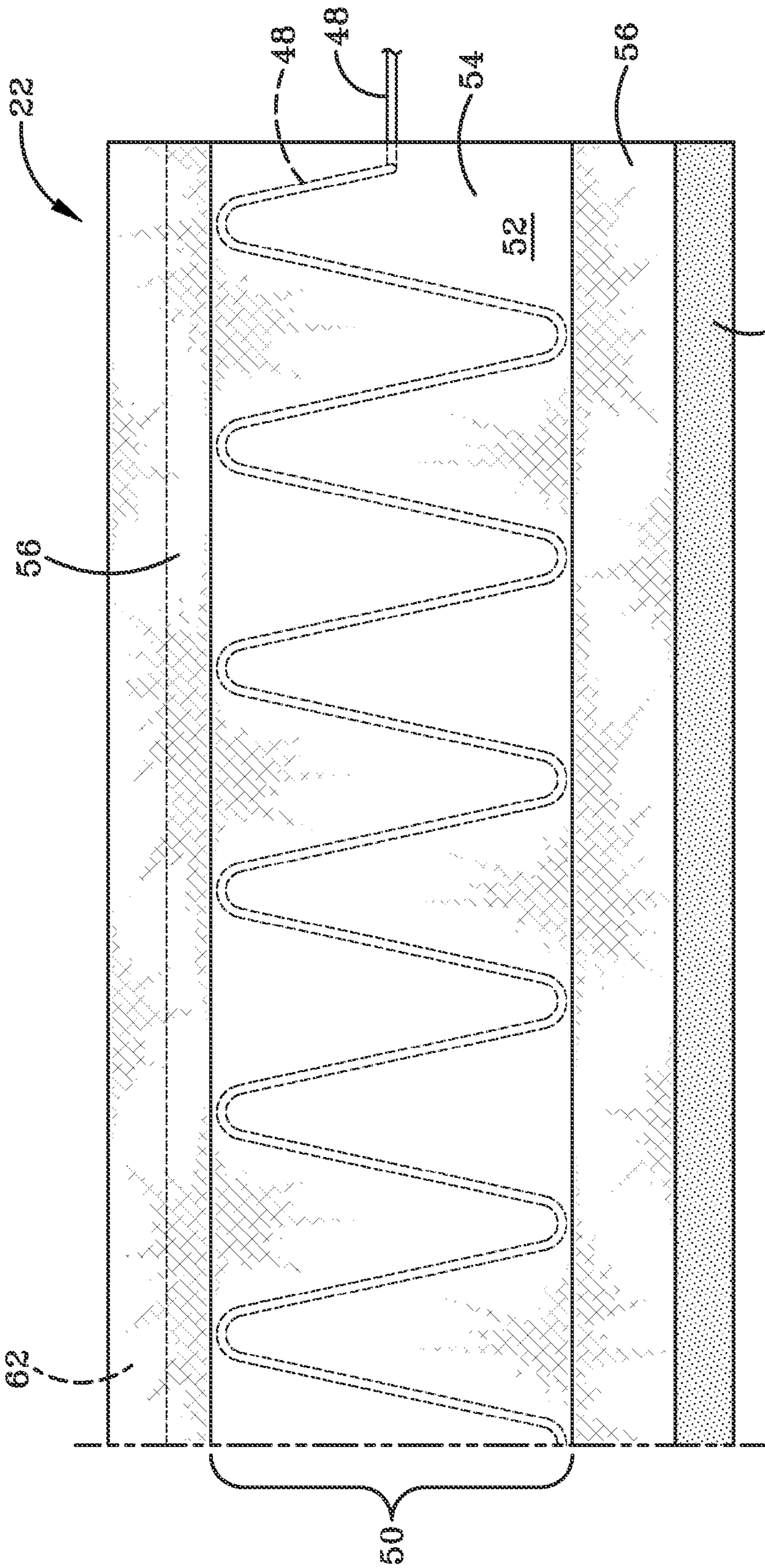
FIG – 1



FIG—3

FIG—2



FIG—3A

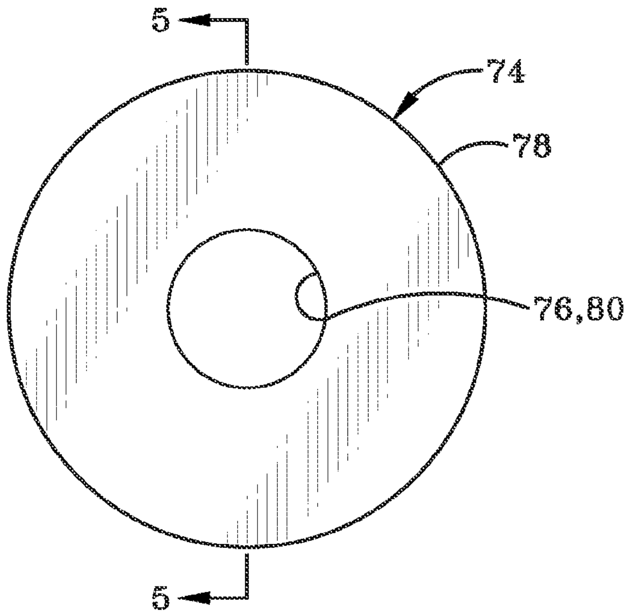


FIG-4

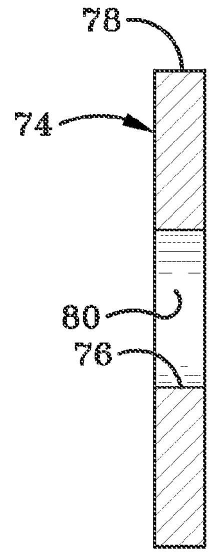


FIG-5

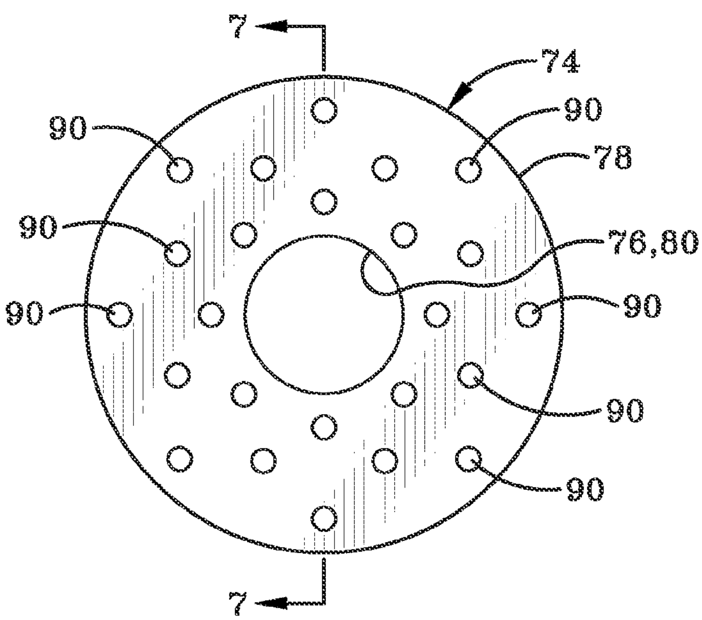


FIG-6

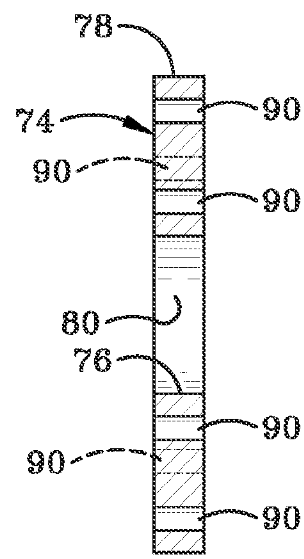


FIG-7

HEATER JACKET FOR A FLUID LINE

FIELD OF THE INVENTION

This disclosure relates generally to semiconductor processing equipment, and more particularly to heater jackets for semiconductor processing fluid lines.

BACKGROUND

Semiconductor fabrication processes are typically conducted with the substrates supported within a chamber under controlled conditions. Some of the important controlled conditions include, but are not limited to, fluid flow rate into the reaction chamber, temperature of the reaction chamber, temperature of the fluid flowing into the reaction chamber, and temperature of the fluid throughout the fluid line.

Fluid lines are generally used to convey an applicable fluid from a source container or other supply apparatus to the reaction space for processing. The fluid line may carry a liquid, gaseous, or even solid containing solution material depending on the application. Further, the size, shape, and arrangement of the fluid lines may be custom designed based on precursor demands and space constraints within the semiconductor fabrication facility.

In order to obtain a consistent reaction environment, maintaining the correct flow rate of precursor at a correct temperature are among the key factors. However, the importance of maintaining the temperature of the precursors at a uniform temperature is not limited to just the reaction chamber. A number of precursors have a limited temperature range of gaseous phase composition. Thus, in order to maintain the correct flow rate, the precursor must be maintained within a slim temperature range from the source container, through the fluid line, and finally into the reaction chamber.

A number of heater jackets have been developed in an attempt to maintain consistent fluid temperatures during the transition from the temperature controlled source container to the reaction chamber. One common example is cloth heater jackets which surround the fluid line and include a cloth inner layer in contact with the fluid line. The cloth heater jacket may be generally flexible, but is difficult to position on fluid lines with bends. Further, if a heating element is also included, the heating element is generally in contact with or close to the fluid line and a thermocouple may inadvertently read higher or lower temperatures because the heating element is contacting the same surface as the thermocouple. Still further, since the heater jacket is in direct contact with the fluid line, there may be additional wear and tear on the inner surface of the heater jacket from the contact with the fluid line, particularly around bends in the fluid line or at microfittings.

An alternative to heater jackets includes heat tape, which is inexpensive but time consuming to install. Further, when a section of the fluid line needs to be worked on or replaced, the heat tape must be removed, scraped, and a new section installed in its place.

SUMMARY

Various aspects and implementations are disclosed herein that relate to heater jackets and methods of maintaining a temperature in a semiconductor processing tool. In one aspect, a heater jacket for a fluid line may include a tube having an inner surface and an outer surface, a spacer disposed within the tube between the inner surface and the fluid line, and wherein the spacer includes a hole for receiving the fluid line therein and spaces the fluid line from the tube inner surface.

In an implementation, the inner surface may further include a recess. A heater element may be disposed within the recess. The heating element may provide radiant heating to the fluid line. The recess may be spirally disposed within the inner surface. The spacer may further include an outer surface in contact with the tube inner surface. The spacer may be solid between the spacer hole and the spacer outer surface. The spacer may include a plurality of apertures between the spacer hole and the spacer outer surface. The plurality of apertures may be pores.

A plurality of spacers may be disposed along a length of the fluid line. A fluid line temperature between each spacer is the same throughout the length of the fluid line. A fluid line temperature between each spacer varies throughout the length of the fluid line. The fluid line may further include a microfiting and one of the plurality of spacers is located on each side of the microfitting. The microfitting may include a 45 degree angle bend. The tube inner surface may or may not contact the microfitting. An air gap may be located between the tube inner surface and the fluid line outer surface to radiantly heat the fluid line with a heating element.

In another aspect, a reaction system may include a reaction chamber operatively connected to a fluid line, the fluid line including a tube having an inner surface and an outer surface, a spacer disposed within the tube between the inner surface and the fluid line, and wherein the spacer includes a hole for receiving the fluid line and spaces the fluid line from the tube inner surface.

The reaction system may include a plurality of spacers, wherein the tube inner surface contacts the plurality of spacers and does not contact the fluid line. A heating element may be embedded in the tube inner wall and providing radiant heat to the fluid line. The spacer may be solid between the spacer hole and a spacer outer surface. The spacer may further include a plurality of apertures between the hole and a spacer outer surface. The spacer may further include a first half having a pair of through holes and a second half having a pair of threaded holes and a pair of screws are inserted through the first half through holes and screwed into the second half threaded holes to mount the spacer on the fluid line. A heating element may be embedded in the tuber inner wall and provide convection heating to the fluid line.

In still another aspect, a method of maintaining a fluid temperature in a semiconductor processing machine including the steps of: providing a reaction chamber in communication with a fluid line wherein the fluid line includes a tube having an inner surface and an outer surface, a spacer disposed within the tube between the inner surface and the fluid line, and wherein the spacer includes a hole for receiving the fluid line and spaces the fluid line from the tube inner surface, providing a heating element between the fluid line and the tube, powering the heating element to increase a temperature of a fluid between the fluid line and the tube, monitoring a temperature of the fluid line, and controlling the temperature of the fluid between the fluid line and the tube in response to monitoring the temperature of the fluid line.

This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter. Furthermore, the claimed subject matter is not limited to implementations that solve any or all disadvantages noted in any part of this disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** schematically shows a cross-section of a semiconductor process module with fluid lines connecting the module and the source containers.

FIG. **2** is a longitudinal sectional view of a fluid line with a heater jacket.

FIG. **3** is a sectional view of the fluid line and heater jacket taken generally about line **3-3** in FIG. **2**.

FIG. **3**A is a front view of a heater jacket laid open to illustrate the interior of the heater jacket.

FIG. **4** is a front view of a fluid line spacer.

FIG. **5** is a sectional view of a fluid line spacer taken generally about line **5-5** in FIG. **4**.

FIG. **6** is a front view of a fluid line spacer.

FIG. **7** is a sectional view of a fluid line spacer taken generally about line **7-7** in FIG. **6**.

DETAILED DESCRIPTION

FIG. **1** illustrates a semiconductor reaction chamber **10** having a reaction space **12** therein. For brevity, the internals of the reaction space **12** have been simplified and/or removed and are not intended to be limiting. It should be readily apparent that any reaction space **12** or reaction chamber **10** may be utilized. Further, reaction space **12** may include a first inlet port **14** adapted to receive a microfitting or adapter **16** therein. A second inlet port **18** may also be formed in reaction chamber **10** and also include a microfitting or adapter **20** therein. While the exemplary embodiment only illustrates and describes two inlet ports in reaction chamber **10**, any number of inlet ports are within the spirit and scope of the present disclosure.

A heater jacket **22** and a heater jacket **24** are each shown intermediate a precursor source **26** and a precursor source **28** respectively. Specifically, heater jacket **22** surrounds a fluid line **30** and heater jacket **22** may include an outer surface **32**, one or more bends **34**, and an attachment portion **36**. In one implementation, attachment portion **36** may be a hook and loop fastener to permit easy installation and removal of heater jacket **22** from fluid line **30**.

Heater jacket **24** is illustrated surrounding a fluid line **38** and heater jacket **24** also includes an outer surface **40** and an attachment portion **42** having a plurality of buttons or snaps **44** to secure the free ends at attachment portion **42**. In the remaining FIGS, heater jacket **22** is described in greater detail. The only difference between heater jacket **22** and heater jacket **24** is the way in which the free ends are connected to one another to surround the appropriate fluid line. A person of ordinary skill in the art will immediately recognize that either closure mechanism, or a variety of suitable alternatives, may be utilized without departing from the spirit and scope of the disclosure. Further, while only two heater jackets are shown, any suitable number of heater jackets may be utilized, including multiple heater jackets for each fluid line.

Referring to FIGS. **2** and **3**, heater jacket **22** and fluid line **30** are both illustrated in a longitudinal section view and a cross-sectional view, respectively. Heater jacket **22** may include an insulation material **46** attached to outer surface **32** to retain any heat generated by a heating element **48** within the heater jacket. Insulation material may be a silicone rubber, fiberglass, a flexible insulating material, or any suitable alternative. Heating element **48** may be a resistive wire heater, a ceramic heater, a band-type heater, or any other suitable heating method or apparatus. As illustrated in FIGS. **2** through **3**A, heating element **48** may be located within heating area **50** of inner surface **52** and may be helically or spirally oriented by way of non-limiting example. Further, an inner protective layer **54** is secured against inner surface **52** to locate heating element **48** therein. In one aspect, heating element **48** may be partially recessed within insulation material **46** to promote a flush inner surface on heater jacket **22**.

Outward of heating area **50** are free ends **56** which meet to secure fluid line **30** within heater jacket **22** during operation. As discussed previously, attachment point **36** secures free ends **56** together during operation. Attachment point **36** may be formed with a fixed end **58** secured to one of the free ends and a hook portion **60** extending from fixed end **58**. A loop portion **62** may be attached to the other free end opposite fixed end **58** for receiving the hook portion **60** when securing fluid line **30** within the heater jacket.

As best seen in FIG. **2**, protective layer **54** also at least partially defines an inner surface or inner cavity **64**. Inner cavity **64** surrounds fluid line **30** and due to the gap between protective layer **54** and fluid line **30**, heating element **48** is able to provide radiant or convection/oven style heating to the fluid line. Fluid line **30** also include an outer surface **66** and an inner surface **68**, with inner surface **68** arranged to transport a fluid from precursor source **26** to reaction chamber **10**. A plurality of microfittings **70** are disposed along the length of fluid line **30** and help the fluid line transition through bends. Still further, microfittings **72** may be used to connect two distinct pieces of a fluid line together.

Heater jacket **22** also includes a plurality of spacers **74** disposed within the heater jacket between protective layer **54** (an inner surface of the heater jacket) and fluid line **30**. Advantageously, spacers **74** assist by providing a gap between protective layer **54** and fluid line outer surface **66**. The gap or inner cavity **64**, as discussed above, provides an air or gas filled medium for radiantly heating fluid line **30**. In addition to providing inner cavity **64**, spacers **74** also assist in preventing protective layer **54** from contacting fluid line **30**. This provides a number of advantages including, but not limited to, preventing heat spikes or hot spots and preventing damage to the heater jacket caused by friction from the fluid line rubbing against the inner surface of the heater jacket. Each spacer **74** includes an inner surface **76** generally adjacent fluid line **30** and an outer surface **78** generally adjacent protective layer **54**. Inner surface **76** defines a hole **80** for receiving fluid line **30**. In one aspect, hole **80** is sized slightly larger than fluid line outer surface **68** so that spacer **74** can easily slide into position on fluid line **30**, but is small enough that it will not move too easily.

Fluid line **30** may be any suitable tube capable of transporting a chemical from the source container to the reaction chamber. Typical fluid lines may have an outside diameter of ¼" to ⅜", although any size fluid line is within the spirit and scope of the disclosure, including fluid lines having an OD greater than 1". When a ¼" OD fluid line is being utilized, spacers **74** may be any suitable size, such as 18.5 mm OD with a thickness of 0.25mm to 3mm and preferably 1 mm thick. Nevertheless, the OD of spacer **74** may easily range from 7 mm to 50 mm or larger. When enclosing a ⅜" OD fluid line, the sizes and ranges of the spacer **74** OD would increase substantially.

In one aspect, spacers **74** are strategically placed on both sides of each microfitting to guarantee that the heater jacket does not touch fluid line **30** at the microfitting or on either side of the microfitting. Further, spacers **74** may be spaced apart strategically to selectively heat certain portions of the fluid line more efficiently. For example, fluid flow in bends or at microfittings may create some turbulent flow and restrict proper fluid flow. In this instance it may be important to increase the temperature by 10-50 degrees C. in those areas.

By locating spacers on each side of the affected area, the heating element in the affected area can be raised to a higher temperature to prevent condensation and promote more efficient fluid flow. On the other hand, the adjacent zones (as defined by each set of spacers **74**) may be maintained as the appropriate temperatures to guarantee that the particular fluid within fluid line **30** remains at a temperature above the condensation range regardless of the fluid's location within fluid line **30**.

The temperature ranges may be from as low as room temperature to upwards of 800 degrees C. depending on the materials being transmitted through the fluid line and the material used to encapsulate the heater elements within the heater jacket. In one aspect, the preferred maximum temperature is 200 degrees C. Further, the temperature range is ideally controlled within a +/−10 degree C. range and even more preferably a +/−5 degree C. range.

FIG. **2** also illustrates a plurality of thermocouples **82** mounted to fluid line **30** with clamps **84** to measure the temperature of fluid line **30** directly. Thermocouples **82** may each include a single function of being a control temperature thermocouple **82** or an over-temperature thermocouple **82**. Regardless of which function each thermocouple **82** performs, each thermocouple **82** is connected to a monitoring unit **86** through outputs **88**. In one aspect, the thermocouple may perform both the control temperature function and the over-temperature function, or two separate thermocouples may be mounted at the same clamp **84** to provide both readings. In one implementation, a control temperature thermocouple **82** and an over-temperature thermocouple **82** may each be located between a pair of spacers **74** to properly maintain the temperature within that particular zone or region. Providing separate thermocouples **82** for each zone may be necessary if each zone is maintained at different temperatures or even if all the zones are set to the same temperature to ensure continuity in the temperature throughout the fluid line. Although not specifically shown in the FIGS, each thermocouple output **88** must extend through an opening in the heater jacket. These openings may be sealed or sleeved to prevent any temperature lose to the ambient air.

FIGS. **4** through **7** illustrate two non-limiting examples of spacers **74** which may include a radius or rounded portion on each edge to prevent damage to the inner surface of the heater jacket. Specifically, FIGS. **4** and **5** illustrate a solid spacer **74**, while FIGS. **6** and **7** illustrate a spacer **74** having a plurality of apertures **90** therein.

Solid spacer **74** shown in FIGS. **4** and **5** may be used in applications where the desired temperature control regime is identical throughout the length of the fluid line or in applications where the temperature changes at each zone or between each spacer. As can be seen, spacer **74** is solid between inner surface **76** and outer surface **78** and includes spacer hole **80** therein. In one implementation, spacer **74** may be composed of stainless steel with approximately a 1 mm thickness and an outside diameter of approximately 18.5 mm. Spacer **74** may also be composed of any number of alternative materials, including but not limited to, plastics, aluminum, or any other suitable material.

Similarly, spacer **74** with apertures **90** may be used in applications where the desired temperature control regime is identical throughout the length of the fluid line or in applications where the temperature changes at each zone. Advantageously, apertures **90** may be used to permit continuity between zones and particularly at each area directly adjacent the spacer since heated air may be able to pass through apertures **90**. Still further, the shape and size of apertures **90** is not limited to circles or those shown in FIGS. **6** and **7**, but may instead be any shape or size suitable for the application. For example, the size of apertures **90** may be restricted to reduce the amount of heated air passing there through on one end of a zone, while the apertures on the opposite spacer may be large to permit additional heated air flow. As can be seen, a number of modifications are within the spirit and scope of the disclosure without significant modifications.

In addition, a variety of spacers **74** may be used in a single fluid line heater jacket. By way of non-limiting example, a heater jacket may utilize solid spacers **74** on each end of the microfittings and spacers **74** with apertures during straight sections of the fluid line or vice versa.

Spacers **74** may also be include multiple pieces attached together to form a single spacer. For example, spacer **74** may be two half pieces which through holes in one half and threaded holes in the opposite half so that an attachment bolt can be directed through the through holes and screwed into the threaded holes. Advantageously, this arrangement would simply installation, allow retrofitting of old fluid lines with the spacer heater jacket system without disconnecting the fluid lines, and thereby reduce overall expenses for the heater jackets. While a through hole with threaded holes is one means to secure two spacer halves, a locking clip, adhesive, welding, solder, or any other attachment means may be utilized.

Heater jacket **22** also provides an easier and simpler method to control the temperature of the fluid line. Prior to securing heater jacket **22** around fluid line **30**, the appropriate spacers **74** (either being solid, having apertures, or a combination of both) may be located on fluid line **30**. The heater jacket is then secured around fluid line **30** and spacers **74** and fastened at attachment portion **76** using hook portion **60** and loop portion **62**. After securing the appropriate outputs **88** from the various thermocouples **82** to monitoring unit **86**, heating element **48** is powered to the appropriate temperature to heat the air gap between the protective layer **54** and fluid line **30** to heat the fluid therein by radiant heating or convection heating. The thermocouples then provide data on both the control temperature and the over-temperature to the monitoring unit, where the monitoring unit is then capable of increasing or decreasing the power to heating element **48** as appropriate.

While the present disclosure merely illustrates a single heating element in a single heater jacket for a fluid line, it is within the spirit and scope of the disclosure to incorporate multiple separate heating elements within a single heater jacket. By way of non-limiting example, a separate and distinct heating element may be incorporated at each and every heating zone to more accurately control the various temperatures in the fluid line, regardless if different temperatures are required in different zones.

In one aspect, the precursors or fluids transported within the fluid line may be TEMAH, TBTDET, $TaCl_5$ H_2O. TEMAH is a specific example with a service temperature of approximately 90 degrees C. and a decomposition temperature of approximately 100 degrees C. If any portion of the fluid line in less than 90 degrees C., condensation forms and if any fluid line is greater than 100 degrees C., decomposition occurs. Thus it is seen that precise control of the fluid line is highly desired.

These and other embodiments for methods of using and apparatus for heater jackets for a fluid line may incorporate concepts, embodiments, and configurations as described with respect to embodiments of apparatus for susceptors described above. The particular implementations shown and described are illustrative of the invention and its best mode and are not intended to otherwise limit the scope of the aspects and implementations in any way. Indeed, for the sake of brevity, conventional manufacturing, connection, preparation, and other functional aspects of the system may not be described in detail. Furthermore, the connecting lines shown in the various figures are intended to represent exemplary functional relationships and/or physical couplings between the various elements. Many alternative or additional functional relationship or physical connections may be present in the practical system, and/or may be absent in some embodiments.

As used herein, the terms "comprises", "comprising", or any variation thereof, are intended to reference a non-exclusive inclusion, such that a process, method, article, composition or apparatus that comprises a list of elements does not include only those elements recited, but may also include other elements not expressly listed or inherent to such process, method, article, composition or apparatus. Other combinations and/or modifications of the above-described structures, arrangements, applications, proportions, elements, materials or components used in the practice of the present invention, in addition to those not specifically recited, may be varied or otherwise particularly adapted to specific environments, manufacturing specifications, design parameters or other operating requirements without departing from the general principles of the same.

What is claimed is:

1. A heater jacket for a fluid line comprising:

a tube having an inner surface, an outer surface and an attachment mechanism to permit installation and removal of the tube from a fluid line by attaching free ends of the heater jacket together;

a heating element between the inner surface and the outer surface;

a spacer disposed within the tube between the inner surface and the fluid line configured to define a cavity between the inner surface and the fluid line, said cavity configured to allow radiant heat from the heating element to heat fluid within the fluid line and to prevent the heater jacket contacting the fluid line; and

wherein the spacer includes a hole for receiving the fluid line therein and spaces the fluid line from the tube inner surface, and

wherein the fluid line is configured to transport a fluid from a precursor source to a reaction chamber.

2. The heater jacket of claim **1** wherein the inner surface further comprises a recess.

3. The heater jacket of claim **2** wherein the heating element is disposed within the recess.

4. The heater jacket of claim **2** wherein the heating element provides convective heating to the fluid line.

5. The heater jacket of claim **2** wherein the recess is spirally disposed within the inner surface.

6. The heater jacket of claim **1** wherein the spacer further comprises an outer surface in contact with the tube inner surface.

7. The heater jacket of claim **6** wherein the spacer is solid between the spacer hole and the spacer outer surface.

8. The heater jacket of claim **6** wherein the spacer further comprises a plurality of apertures between the spacer hole and the spacer outer surface to facilitate convective heating of the fluid line.

9. The heater jacket of claim **8** wherein the plurality of apertures are pores.

10. The heater jacket of claim **1** further comprising a plurality of spacers disposed along a length of the fluid line.

11. The heater jacket of claim **10** wherein a fluid line temperature between each spacer is approximately the same throughout the length of the fluid line.

12. The heater jacket of claim **10** wherein the heater jacket heats portions of the fluid line based on the placement of the spacers.

13. The heater jacket of claim **10** wherein the fluid line further comprises a bend and one of the plurality of spacers is located on each side of the bend.

14. The heater jacket of claim **1** wherein the fluid line has an outside diameter of ¼ inch to ⅜ inch.

15. The heater jacket of claim **13** wherein the tube inner surface does not contact the bend.

16. The heater jacket of claim **1**, wherein the heater jacket comprises one or more spacers that are solid between the spacer hole and the spacer outer surface and one or more spacers that comprise apertures between the spacer hole and the spacer outer surface.

17. A reaction system comprising:

a reaction chamber fluidly connected to a fluid line;

a precursor source fluidly coupled to the fluid line;

a heater jacket for the fluid line, the heater jacket comprising a tube having an inner surface, an outer surface and an attachment mechanism to permit installation and removal of the heater jacket from the fluid line by attaching free ends of the heater jacket together, a spacer disposed within the tube between the inner surface and the fluid line configured to prevent the heater jacket from contacting the fluid line, said cavity configured and to define a cavity between the inner surface and the fluid line, said cavity configured to allow radiant heating by the heating element of the fluid line, and a heating element between the inner surface and the outer surface; and

wherein the spacer includes a hole for receiving the fluid line and spaces the fluid line from the tube inner surface.

18. The reaction system of claim **17** further comprising a plurality of spacers, wherein the tube inner surface contacts the plurality of spacers and does not contact the fluid line.

19. The reaction system of claim **17** wherein the tube comprises an inner wall comprising the inner surface and wherein the heating element is embedded in the tube inner wall and provides radiant heat to the fluid line.

20. The reaction system of claim **17** wherein the spacer is solid between the spacer hole and a spacer outer surface.

21. The reaction system of claim **17** wherein the spacer further comprises a plurality of apertures between the hole and a spacer outer surface.

22. The reaction system of claim **17** wherein the spacer further comprises a first half having a pair of through holes and a second half having a pair of threaded holes; and

wherein a pair of screws are inserted through the first half through holes and screwed into the second half threaded holes to mount the spacer on the fluid line.

23. The reaction system of claim **17** wherein the heating element is embedded in the tube inner wall and provides convection heating to the fluid line.

24. A method of maintaining a fluid temperature in a semiconductor processing machine comprising the steps of:

providing a reaction chamber in communication with a fluid line and a heater jacket surrounding at least a portion of the fluid line, wherein the heater jacket comprises a tube having an inner surface, an outer surface, a heating element, and an attachment mechanism to permit installation and removal of the heater jacket from the fluid line by attaching free ends of the heater jacket together, a spacer disposed within the tube between the inner surface and the fluid line to define a cavity between the inner surface and the fluid line to allow radiant heat from the heating element to radiantly heat the fluid line and to prevent the heating element from contacting the fluid line; and wherein the spacer includes a hole for receiving the fluid line and spaces the fluid line from the tube inner surface;

powering the heating element to increase a temperature of a fluid between the fluid line and the tube;

monitoring a temperature of the fluid line using a thermocouple mounted to the fluid line; and,

controlling the temperature of the fluid between the fluid line and the tube in response to monitoring the temperature of the fluid line.

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